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ABSTRACT

Several concepts and techniques used to design computer simulation of human performance were employed in developing an information processing approach to task analysis. This new approach is compared and contrasted with Gagne's hierarchical task analysis model. Two conceptual levels of a behavioral objective are identified. One level, referred to as the "task level," is concerned with the determination of the subskills that are required to learn and perform the terminal objective of a task. The second level, the "rule level," is concerned with the discovery of order relationships between subskills. Neither hierarchical nor information processing analysis would be sufficient for all types of tasks. A hierarchical analysis would be appropriate where lower ordered skills generate positive transfer to higher level skills, while an information processing analysis would be utilized where the output of one task subskill or operation is required as input for a succeeding operation (behavior chaining). (Author/JY)

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TECH MEMO

TASK ANALYSIS - AN INFORMATION PROCESSING APPROACH

Paul F. Merrill

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TASK ANALYSIS - AN INFORMATION PROCESSING APPROACH

ABSTRACT

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TASK ANALYSIS - AN INFORMATION PROCESSING APPROACH[1]

Paul F. Merrill

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The purpose of this paper is to propose and describe an information processing approach to the problem of task analysis. In addition, this new approach will be compared and contrasted with Gagné's hierarchical task analysis model (Gagné, 1962, 1968, 1970). A learning task or behavioral objective may be analyzed at two different conceptual levels. An analysis at the first level, which shall be referred to in this paper as the "task level," is concerned with the determination of the subskills that are required to learn and perform the terminal objective of a task. Analysis at the "task level" is also concerned with the discovery of ordered relationships between the subskills. On the other hand, an analysis at the second, or "rule level" entails the determination of the most effective instructional paradigm for teaching a particular subskill, rule, or operation. Briggs (1968) has made a similar distinction between "what is taught" and "how it is taught."

Although there are strong implications for the use of information processing techniques in the analysis of tasks at the "rule level," the major thrust of this paper will be to describe the manner in which an information processing approach may be used to analyze a learning task or terminal behavior at the "task level." Evans, Homme, and Glaser (1962) have suggested that task subskills may be related according to: 1) complexity (from the simple to the complex), 2) chronology (time sequencing often

[1]The collaboration of William P. Olivier and C. Victor Bunderson with the author in the early formulation and devlopment of the ideas presented in this paper is gratefully acknowledged.

used in history courses), 3) spatiality (as in a geography program), or 4) interdependencies (as in a mathematics program). The task analysis models which will be described and contrasted in this paper are concerned with the analysis of tasks with subskills related according to Evans, Homme, and Glaser's fourth category of interdependence (Evans et al., 1962).

The most widely accepted model of task analysis for determining the interdependencies between subskills has been proposed by Gagné, (1962). He proposed that in analyzing a terminal objective it is possible to define a hierarchy of subskills such that lower ordered skills or behaviors would generate positive transfer to skills at a higher level. Such an analysis may be performed by starting with the terminal behavior and identifying subordinate skills by asking the question: ''What would an individual already have to know how to do in order to learn the new capability simply by being given verbal instructions?'' This question is asked recursively of each subbehavior identified until the assumed student entry behaviors are determined. In the strictest sense, the question quoted above implies that an individual must already know how to do subordinate behaviors before he can learn a higher or superordinate level behavior. In an empirical sense, the question implies that subordinate skills will facilitate or transfer positively to the learning of superordinate skills.

Although Gagné's hierarchical task analysis has received considerable empirical support in a number of studies using mathematical materials (Gagné, 1962; Gagné and Paradise, 1961; Gagné, Major, Garstens, and

Paradise, 1962), some instructional designers have attempted to used Gagné's procedure to analyze tasks in which subskills are not hierarchically related. The inappropriate use of this procedure has led to the erroneous conclusion that certain subskills of a given task must be learned before other subskills can be taught. The subskills for many tasks are not interdependently related, and the subskills for other tasks have information processing interdependent relationships rather than hierarchical relationships.

Information Processing Approach

If the terminal behavioral of a task requires an individual to perform a set of subskills which have an information processing relationship, then the task may be thought of as an information processing task or procedure. An information processing procedure may be defined as one which requires one or more inputs from a given domain and produces one or more outputs having a specified relationship to the inputs (Knuth, 1968). This definition implies that the subskills or operations of a task have an information processing relationship if, and only if, the result or outputs of one operation are required as part of the inputs for a succeeding operation. This ''output-input'' relationship of an information processing procedure is demonstrated in Figure 1. The output of the summing operation becomes the input for the succeeding division operation. Obviously, the sequence for performing the operations of such a task becomes very crucial. It would be impossible to perform correctly certain operations of the procedure until the results or outputs of previous operations had been obtained.

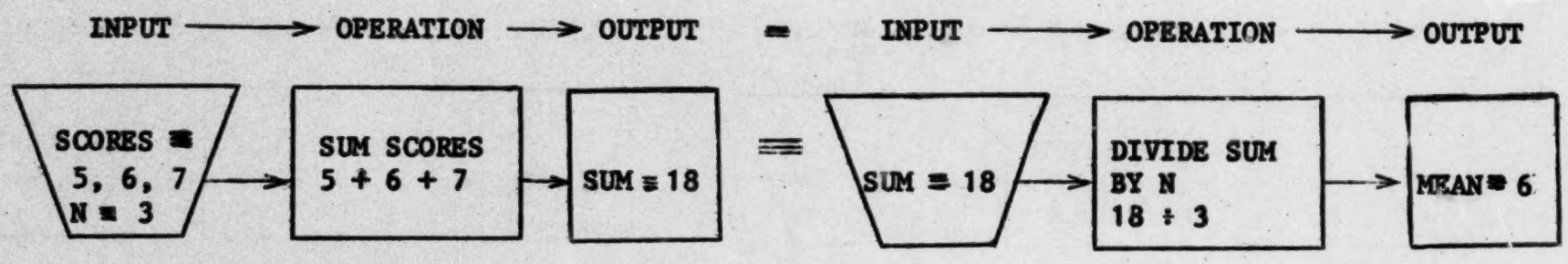

Figure 1.--Output - Input Relationship of an Information Processing Procedure

An information processing task may be thought of as either an algorithmic procedure or a heuristic procedure. An algorithmic procedure consists of a set of operations which are guaranteed to produce the terminal behavior, while a heuristic procedure is made up of ''rules of thumb'' which generally will lead to a solution but do not guarantee the attainment of the terminal behavior.

The subskills required to perform an information processing task may be determined by analyzing how a man goes about performing the task. If the task requires physical activity, an observation of the man actually performing the task should be conducted. If the task entails cognitive operations, it may be necessary to use a technique such as that described by Feldman (1963) where a man is asked to ''think aloud'' while performing the task. Detailed notes may be made concerning the information or objects being operated upon, the specific operations being performed, the results of each operation, and all decision points encountered. The purpose of this analysis is not to determine how a naive or untrained person would approach the given task, but to determine the most efficient and effective procedure for performing the task. Therefore, the man who is observed and asked to ''think aloud'' should be an expert, or in Gilbert's terms, a ''master'' at the task (Gilbert, 1962).

The information obtained during the observation may be used to outline the information processing procedure. The steps of the procedure should be specified in a precise and unambiguous manner, and each step should be stated in terms of a process or operation to be performed. A flow-chart of the procedure should be drawn which shows the sequence for performing the operations, the decision point branches, and any required

iterative loops. The validity of the flowchart and corresponding procedure may be determined by stepping through each operation of the flowchart by hand, using several different initial inputs. Care should be taken to verify that the necessary inputs are available for each successive operation. These inputs may be available either from initial inputs or from the outputs from previous operations. Decision point branches should be checked to make sure they provide for all possible contingencies.

Figure 2 is a flowchart of an information processing procedure for reconciling a bank statement. This particular task is usually taught in a high school general business course and requires the performance of both physical and cognitive operations. An examination of the flowchart will reveal that the output or results from earlier operations are used as inputs for succeeding operations. However, these steps are not hierarchically related, since a person could learn how to do later steps without knowing how to perform earlier steps. The flowchart also depicts the fact that certain successive operations in the procedure may not have information processing interdependencies. For example, the operations labeled 4, 5, and 6 are not interdependent and may be performed in any order. However, the independent output of each of these operations is required as part of the input for the performance of operation number 7.

The size of the steps or complexity of the operations specified in the flowchart may be somewhat arbitrary. The appropriate degree of complexity for each operation is dependent upon the processing capabilities of the target population which must perform the operation. A determination of the optimal complexity for the operations which will be executed by

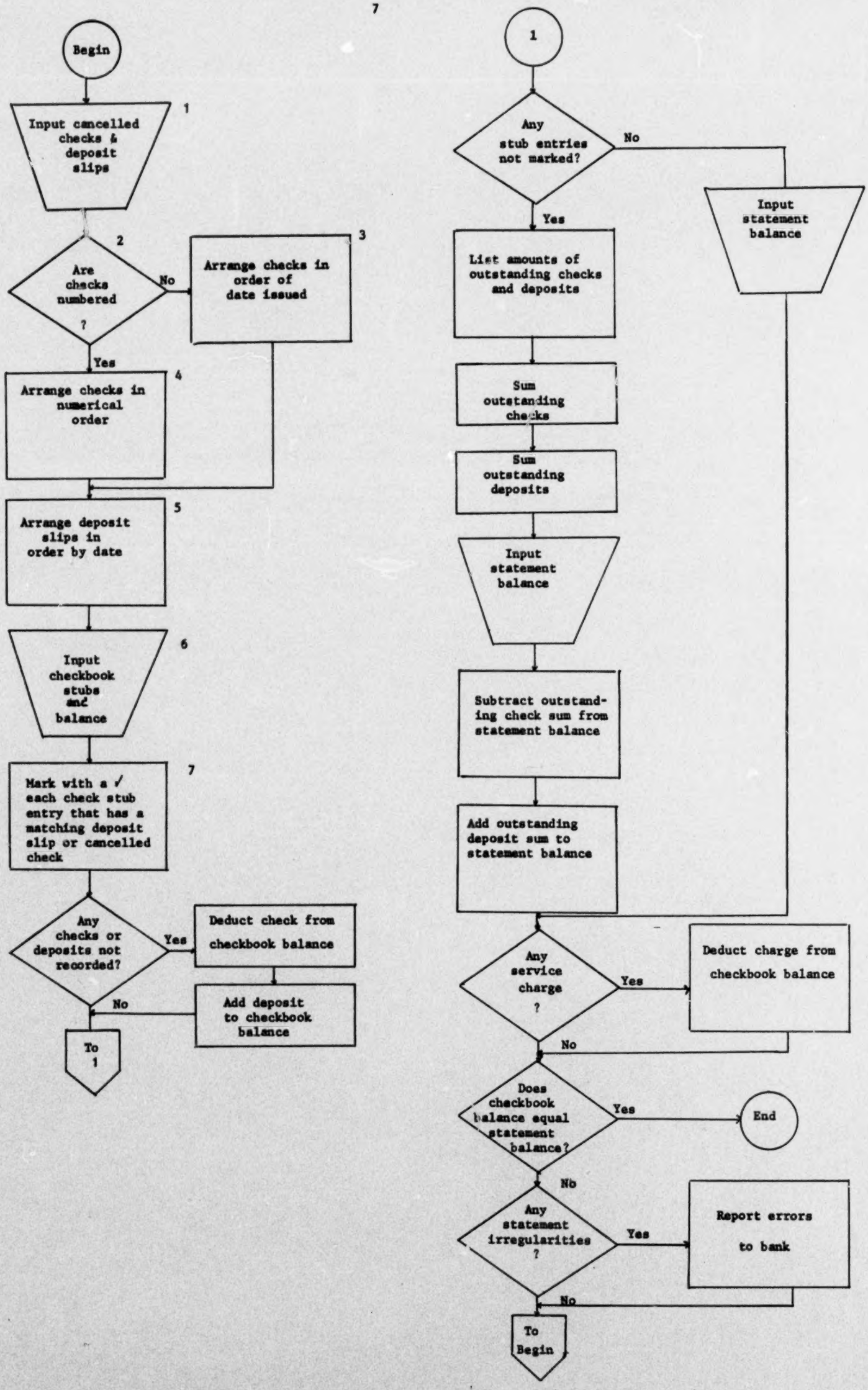

Figure 2.--Information Processing Flowchart for Reconciling a Bank Statement

a given population of subjects is an empirical problem. In the context of the mathetics approach, Gilbert (1962) has suggested that the individual operants should be combined into the largest behavioral unit that a student can reasonably perform. An overestimation of the ''op[illegible]t span'' will be discovered in an empirical tryout and can be easily rectified. However, an underestimation would not lead to any errors and therefore would be very difficult to discover. If an empirical tryout reveals that students are unable to perform a certain operation of the procedure, that operation may be further analyzed into its suboperations. For example, if subjects were unable to perform the fourth operation of ''arranging checks in numerical order,'' a subprocedure for performing a numerical sort could be specified.

For many complex tasks, there may be more than one information processing procedure for performing the terminal behavior. If this is the case, a comparative evaluation of the procedures should be made. The length of time and number of operations required to perform the different procedures given several initial inputs should be compared. The procedures could also be evaluated in terms of Bruner's (1966) concepts of economy and power. He suggests that economy is a function of the sequence of presentation where one procedure may require storage of information, while another may require a more pay-as-you-go type of information processing. In terms of power, one procedure may more enable a student to generate new hypotheses and combinations than some other procedure.

A Comparison of Task Analysis Techniques

When any new approach is presented for attacking an old problem, the first question posed by critics is: ''What is the difference between this new approach and already existing techniques?'' Obviously, many of the ideas embodied in a new approach will be very similar to ideas used in other approaches to the same problem. The hierarchical task analysis procedure (Gagné, 1962) and the information processing analysis both reveal a structure of skills or operations having an ordered relationship to each other. However, the nature of this ordered relationship is considerably different. Two skills or operations have a hierarchical relationship if the learning of one skill is prerequisite to the learning of the other skill. In contrast, two skills or operations have an information processing relationship if the outputs of one operation are required as part of the inputs for another operation. Thus, for hierarchically related skills the learning sequence is important, while for information processing related skills the performance sequence is critical. The use of a hierarchical task analysis procedure to analyze a task which has information processing relationships can lead to erroneous conclusions concerning the relationships between certain operations. For example, one student attempted to conduct a hierarchical analysis of the objective ''the student will be able to apply the rule: Work = Force x Distance'' and concluded that the capabilities of measuring distance and force were hierarchically related to the application of the rule. However, such a conclusion was erroneous since a student can learn how to apply the rule without first learning how to measure distance and force. On the

other hand, the measurement of distance and force do have an information processing relationship to the application of the rule since the rule cannot be correctly applied unless the inputs of distance and force are available. In another case, a hierarchical analysis of the terminal objective ''Each student will produce and document a programmed course of instruction'' was conducted. From the resulting block diagram, one would be led to conclude that before a student could learn how to conduct a summative evaluation he would have to be able to write a programmed text. It is obvious that the summative evaluation of a text cannot be performed until the text is written (an information processing relationship), but the person performing the summative evaluation does not need to know how to write the text being evaluated.

The point of this differentiation between ordered relationships seems to be that neither hierarchical nor information processing analysis is sufficient or applicable for all types of tasks. If in performing a given task, the outputs of one operation are required as inputs for a succeeding operation, then an information processing analysis would be appropriate. On the other hand, a hierarchical analysis would be conducted when one subskill of a task must be learned before another subskill can be learned. If the subskills of a task are not interdependent, then neither the hierarchical nor the information processing analysis would be appropriate. However, one of the major purposes for conducting a task analysis is to discover the nature of the subskill relationships. Therefore, an instructional designer should analyze a given task using both techniques in order to discover if either type of relationship exists. Some tasks,

especially mathematical tasks, may have both types of relationship. For example, the task of ''simplifying an equation by adding and subtracting terms to both sides,'' described and analyzed by Gagné and Paradise (1961), not only has a hierarchical structure, but is performed by using an algorithmic information processing procedure. By conducting both types of analysis, an instructional designer will obtain a broader understanding of the actual nature of a given task and its subskill relationships.

Information Processing Procedures and Chains

On the surface it may appear that an information processing procedure is just a fancy title given to a behavioral chain. However, the following discussion will attempt to show that it is profitable to distinguish between the two terms.

A common referent for the concept ''chain'' is a series of interlocking links. However, the word ''chain'' has been extended by analogy to refer to the psychological phenomena of a series of ''linked'' behaviors. Mechner (1967, p.87) defines a behavioral chain as ''...a sequence of responses where each response creates the stimulus for the next response.'' A slightly different definition is given by Gilbert (1962, p.10): ''A behavior chain is a sequence of stimuli, responses, and reinforcers in which the reinforcer for one response is also the stimulus for the next response.'' These definitions were originally used to describe the phenomenon of an animal going through a series of complex behaviors before being reinforced with a food pellet. Gilbert (1962) cites the example of a rat pulling a lamp cord to turn on a light, then pressing a lever to sound a buzzer, and then going to the food pan to receive a pellet. However, humans

also execute many series of linked behaviors. Reciting the alphabet, tying a shoe lace, writing a name, and reciting a poem are only a few examples of behavioral chains used by humans.

Mechner (1965, 1967) also classifies the following behaviors as chains: (1) conducting a qualitative chemical analysis, (2) trouble-shooting, and (3) solving a mathematical problem. However, these examples are considerably more complex than the examples cited above. These complex behaviors listed by Mechner have several additional characteristics not covered in the definition of a chain. Because of these additional characteristics, these behaviors would more properly be classified as information processing procedures. Although a behavioral chain and an information processing procedure both involve a series of behaviors or operations, the nature of the link or relationship between consecutive operations is considerably different. The link of a chain is formed by the response to one stimulus serving as a stimulus for the next response. However, the links in an information processing procedure have the additional characteristic of the output of one operation or response serving as an input to the next operation. In the former case, a discriminative stimulus serves as the occasion for the next response, while in the latter case the output of a previous operation not only serves as a cue for the next operation, but it is also used as input data for the succeeding operation.

A further distinction between chains and information processing procedures can be derived from the basic difference described above. Since the response to one stimulus merely serves as the occasion or stimulus for the next response in a chain, it logically follows that the final response to any given chain will always be invariant. In contrast, the

final output of an information processing procedure is dependent upon the given initial inputs. From this distinction it also follows that information processing procedures may have decision points with corresponding branches and/or loops, while chains will always be linear.

There is another type of procedure which is a hybrid of the information processing procedure and the chain. This hybrid procedure is analogous to a computer subroutine that does not have any input parameters. Without any variable inputs, such a procedure will be linear and will always produce the same output. However, the outputs of early operations may serve as inputs to succeeding operations. In contrast, an information processing procedure is analogous to a computer subroutine with variable input parameters.

Learning Sequence

One of the purposes for conducting an analysis at the ''task level'' is to determine the most effective sequence for learning the subskills or operations required to perform the terminal task. It cannot be assumed without supporting empirical evidence or logical argument that the most appropriate sequence for performing a series of operations is also the most appropriate sequence for learning the operations. However, Stolurow (1962) hypothesized that sequential arrangements may be found to make a difference in students' cognitive structure and thereby affect their behavior. Since an information processing task must be performed in a certain order, the instructional sequence used to teach the task should facilitate the students' efforts to organize and structure an efficient strategy for performing the task. Therefore, an effective instructional

sequence would be one which clearly showed the output-input relationships between successive operations. These relationships would be clarified by using a sequence which corresponded to the order for performing the operations. This assertion was put to an empirical test in a study by Olivier (1971). In this study the relationship between posttest performance and the degree of conformity to an information processing sequence was investigated. An imaginary science was used as the learning task. A sequence-conformity index was developed to quantify various degrees of nonconformity to the information processing sequence for performing the task. The index had values ranging from zero to unity. A value of 1.00 was assigned for learning the operations in the proposed sequence, and a value of 0.00 was assigned for learning the operations in a completely reversed order. Intermediate values were assigned for various degrees of nonconformity to the information processing sequence.

The results showed that posttest performance decreased as the degree of conformity to the information processing sequence decreased from 1.00 to .25. However, posttest performance increased again when the sequence was completely reversed (index value of 0.00). Ss with an index of 1.00 performed significantly higher on the posttest ($t(47) = 2.72$, $p < .01$) than Ss with an index of .25. These results only partially support the assertion that the operations of an information processing task should be taught in the same sequence in which they should be performed. Additional studies should be conducted to determine if Olivier's findings would be replicated using different information processing tasks.

The effectiveness of the completely reversed sequence leads to the hypothesis that the retrogression sequence suggested by Gilbert (1962) to establish chains might also be effective for teaching an information processing procedure. Other methods for showing the output-input relationships between successive operations of an information processing task, such as Ausubel's ''advanced organizers'' (Ausubel, 1968) and Gilbert's ''Domain Theory'' (Gilbert, 1962) should also be investigated.

Summary

Several concepts and techniques used to design computer simulations of human performance were used in developing an information processing approach to task analysis. This new approach was compared and contrasted with Gagné's hierarchical task analysis model. Neither hierarchical nor information processing analysis would be sufficient for all types of tasks. A hierarchical analysis would be appropriate where lower ordered skills generate positive transfer to higher level skills, while an information processing analysis would be utilized where the output of one task subskill or operation is required as input for a succeeding operation.

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